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IS 11000-2-3 (1994): Fire hazard testing, Part 2: Test methods, Section 3: Bad-connection test with heaters [LITD 1: Environmental Testing Procedure]

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Indian Standard
FIRE HAZARD TESTING
PART 2 TEST METHODS
Section 3 Bad-Connection Test with Heaters

UDC 621.31 : 620.193.5

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NATIONAL FOREWORD

This Indian Standard (Part 2/Sec 3), which is identical with IEC Pub 695-2-3(1984) 'Fire hazard testing: Part 2 Test methods bad-connection test with heaters', issued by the International Electrotechnical Commission, was adopted by Bureau of Indian Standards on the recommendation of Environmental Testing Procedures Sectional Committee and approval of the Electronics and Telecommunication Division Council (LTDC).

The text of the IEC standard has been approved as suitable for publication as Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

- Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

In the adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their place are listed below along with their degree of equivalence for the editions indicated:

<i>International Standard</i>	<i>Corresponding Indian Standard</i>	<i>Degree of Equivalence</i>
IEC Pub 695-2-1 (1980) Fire hazard testing, Part 2: Test methods. Glow-wire Test and Guidance	IS 11000 (Part 2/Sec 1) : 1984 Fire hazard testing : Part 2 Test methods. Glow-wire test and guidance.	Identical
IEC Pub 695-2-2 (1980) Fire hazard testing, Part 2: Needle-flame Test	IS 11000 (Part 2/Sec 2) : 1984 Fire hazard testing: Part 2 Needle-flame test.	Identical
IEC Pub 4046(1978) Paper board, pulp and related terms—Vocabulary (Clause 6.86)	4261:1967 Glossary of terms relating to paper and pulp based packaging materials (Term 'Wrapping Tissue')	Technically equivalent

The concerned technical committee has reviewed the provisions of IEC 51, and IEC 212, referred in this standard and has decided that they are acceptable for use in conjunction with this standard.

Part 1 of this Indian Standard deals with guidance for assessing fire hazards of electrotechnical products. The subsequent parts are intended to deal with the following:

- Test methods,
- Examples of test procedures and interpretation of results,
- Terminology, and
- Survey of test methods.

Only the English Language text in the International Standard has been retained while adopting it in this Indian Standard.

Indian Standard

FIRE HAZARD TESTING

PART 2 TEST METHODS

Section 3 Bad-Connection Test with Heaters

1. Introduction and scope

The best method for testing electrotechnical products with regard to fire hazard is to duplicate exactly the conditions occurring in practice. In most instances this is not possible. Accordingly, for practical reasons, the testing of electrotechnical products with regard to fire hazard is best conducted by simulating as closely as possible the actual effects occurring in practice.

Parts of electrotechnical equipment which might be exposed to excessive thermal stress due to electric effects and the deterioration of which might impair the safety of the equipment shall not be unduly affected by heat and by fire generated within the equipment.

Connections may produce, under certain conditions, for example loosening, insufficient mechanical pressure or faulty installation, high heat dissipation due to wattage losses depending on their design and the actual current passing through them.

The test described in this standard is applicable to electrotechnical equipment and to its sub-assemblies and components.

2. Object of the test

Connections may, under certain conditions, be a source of heat such that, after a long period, parts of insulating material retaining these connections in position are likely to be unduly affected.

Bad connection denotes a fault condition in a terminal or termination which may give rise to the production of abnormal heat.

The bad connection test with heaters is a test intended to simulate such an overheated connection, consideration being given to the design of the connection and to the current passing through it under normal conditions of use, in order to assess the fire hazard by a simulation technique.

The test is only intended to be applied to screw connections which the user or service man is required to make during the installation, servicing or maintenance of the equipment and which are therefore outside the manufacturer's control. The test is applicable to screw connections having a rated current not exceeding 63 A.

Note. — Advice is given to check other types of connections by type tests and quality control procedures. The glow-wire test (see IEC Publication 695-2-1: Fire Hazard Testing, Part 2: Test Methods — Glow-wire Test and Guidance) or the needle-flame test (see IEC Publication 695-2-2: Part 2: Test Methods — Needle-flame Test) may be applicable to such insulated connections.

3. General description of the test

If possible the specimen should be a complete equipment, sub-assembly or component. If it is necessary to take away parts of an enclosure or to cut off a suitable part to perform the test within the product, care should be taken to ensure that the test conditions are not

significantly different from those occurring in normal use with regard to shape, ventilation, effect of thermal stresses and possible flames occurring or burning or glowing particles falling in the vicinity of the specimen.

If it is not possible to make the test on a sub-assembly or component within the product, the test is made on a separate specimen under the conditions specified in Clause 4.

The test is applied to ensure:

- that a connection, heated under defined conditions by means of an appropriate test heater, does not cause ignition of parts of insulating material, or
- that a part of insulating material, which might be ignited by the overheated connection under defined conditions, has a limited duration of burning, without spreading fire by flames, burning droplets or glowing particles falling from the specimen.

If the specimen is ignited by this method, the fire hazard created may necessitate further tests using other sources of ignition such as the needle-flame.

Note. — The test heaters specified in Clause 4 may not be appropriate for testing terminals and terminations other than those with screw-clamping. Their usability has only been verified for sizes and designs of terminals with screw-clamping as described in Appendix A.

4. Description of test apparatus

The test heater consists of a piece of wire of an alloy containing at least 59% nickel, 14% to 19% chromium and 19% to 23% iron, its specific resistance, at a temperature of 20 °C, being 1.13 Ωmm²/m. The wire has an appropriate length and shape, and each end of it is connected, by means of a copper alloy sleeve, to a lead of circular cross-section, composed of fine-wire copper strands and having a length of 120 ± 2 mm. The sleeves are crimped and subsequently soldered (see Figure 1, page 28).

The shape, the diameter and the length of the resistance wire shall be adapted to the design and the size of the terminal or termination to be tested, taking into account the test power in relation to the actual current carried by the terminal or termination, as specified in Table I.

In order to avoid overheating and melting of the test heater, a specific surface load, related to the diameter and the length of the resistance wire specified above, shall not be exceeded. The actual value n of the specific surface load in watts per square millimetre can be calculated from the formula:

$$n = \frac{N}{\pi \cdot d_h \cdot l_h}$$

and shall be compared with the maximum value n_{\max} for determining the minimum permitted dimensions of the resistance wire,

where:

N = test power, in watts

d_h = diameter of the resistance wire, in millimetres

l_h = free length of the resistance wire, in millimetres,

if $d_h \geq 1.0$ mm, $n_{\max} \approx 0.36$ W/mm², and if $d_h = 0.5$ mm, $n_{\max} \approx 0.40$ W/mm².

The diameter of the stranded leads to be connected to the resistance wire and that of the sleeves shall be chosen on the basis of the heat dissipation caused by the specific type of conductor, solid or stranded, connected under normal conditions of use to the terminal or termination to be tested.

In order to insulate the resistance wire by oxidizing its surface it is necessary to heat the test heater electrically to red hot under normal atmospheric conditions.

For the purpose of subsequent checking of the test heater so as to detect any deterioration, the resistance is measured between the "cold" ends of the stranded leads when new, and is noted.

Note. — Dimensions and shapes of test heaters for certain sizes and designs of terminals with screw clamping for the connection of external copper conductors to electrical equipment, as well as guidance for preparing the test heaters, are given in Appendix A. If other terminals with screw clamping are to be tested, appropriate test heaters can be prepared on the basis of the guidance given in Appendix A.

An adjustable extra-low voltage transformer is used to energize the test heater so as to obtain the test power specified.

The voltmeter and ammeter for measuring the voltage drop across the test heater and the current passing through it should be accurate to 1% (i.e. Class 0.5 according to IEC Publication 51: Recommendations for Direct Acting Indicating Electrical Measuring Instruments and their Accessories). If a wattmeter is used, its accuracy shall be at least 1.5%.

To evaluate the possibility of spread of fire, for example by burning or glowing particles falling from the specimen, one of the following situations need to be specified in the relevant specification:

- if the specimen is tested within the product and if the environment in which the product is to be used is known, a layer of the material or the components normally surrounding or situated underneath the product shall be arranged;
- if the specimen is tested within the product and/or if the environment in which the specimen/product is to be used is unknown, a piece of white pine-wood board, approximately 10 mm thick and covered with a single layer of tissue paper, shall be arranged at a distance of 200 ± 5 mm below the specimen unless otherwise specified in the relevant specification;
- if the specimen is tested separately, it is mounted on a piece of white pine-wood board, approximately 10 mm thick. Before starting the test, the board is conditioned for seven days (168 h) in an atmosphere having a temperature of 23 ± 2 °C and a relative humidity of $50 \pm 5\%$.

Note. — These atmospheric conditions have been taken from Table I of IEC Publication 212: Standard Conditions for Use Prior to and During the Testing of Solid Electrical Insulating Materials.

Wrapping tissue as specified in ISO Standard 4046, Clause 6.86.

Wrapping tissue:

A soft and strong, lightweight wrapping paper of grammage generally between 12 g/m^2 and 30 g/m^2 , primarily intended for protective packaging of delicate articles and for gift wrapping.

5. Severities

The test power and the duration of its application to the specimen shall be specified.

Test power values in relation to the actual current carried by the terminal or termination are given in Table I.

Note. - The values in Table I are based on investigations carried out within the CEE.

The preferred duration of application is 30 min.

TABLE I
Test power values

Current (A)	Test power (W)
Over 0.2 up to and including 0.5	2.0
Over 0.5 up to and including 1.0	4.5
Over 1.0 up to and including 1.5	6.5
Over 1.5 up to and including 2.0	9.0
Over 2.0 up to and including 2.5	11.0
Over 2.5 up to and including 3.0	13.0
Over 3.0 up to and including 4.0	16.0
Over 4.0 up to and including 5.0	19.0
Over 5.0 up to and including 6.0	21.0
Over 6.0 up to and including 8.0	25.0
Over 8.0 up to and including 10.0	29.0
Over 10.0 up to and including 13.0	33.0
Over 13.0 up to and including 16.0	37.0
Over 16.0 up to and including 20.0	42.0
Over 20.0 up to and including 25.0	47.0
Over 25.0 up to and including 32.0	53.0
Over 32.0 up to and including 40.0	60.0
Over 40.0 up to and including 50.0	66.0
Over 50.0 up to and including 63.0	73.0

The tolerance on the values for the test power is $\pm 5\%$.

If required by the relevant specification, other test power values may be specified, but the values quoted in Table I are those which have been measured on bad connections when those currents are flowing.

6. Preconditioning

Unless otherwise specified in the relevant specification, the specimen is stored for 24 h in an atmosphere having a temperature between 15 °C and 35 °C and a relative humidity between 45% and 75% before starting the test.

7. Initial measurements

The specimen shall be examined visually and when specified in the relevant specification the physical/electrical parameters measured.

8. Test procedure

Warning note

Precautions should be taken to safeguard the health of personnel conducting tests against:

- risk of explosion or fire;
- inhalation of smoke and/or toxic products;
- toxic residues.

- 8.1 The room or compartment in which the test is to be carried out shall be substantially draught-free and shall have dimensions sufficient to ensure an adequate supply of air.
- 8.2 For the test, the specimen is arranged in its most unfavourable position of normal use. The means for fixing the specimen in position and for the connection of the test heater to the power supply shall not influence the results of the test in a way other than that occurring under normal conditions of use.
- 8.3 A test heater having the dimensions and shape appropriate for the design of, and the actual current carried by, the terminal or termination to be tested, is inserted into the terminal or termination. The heat is generated as close as possible to the place where a bad connection is likely to occur; care being taken to ensure that the electric and thermal stresses in parts other than that to be tested are reduced to a minimum.
- 8.4 Screws and other clamping means of terminals are lightly tightened, just sufficient to prevent the test heater from coming out during the test, care being taken to ensure that the oxide film of the resistance wire is not damaged so as to cause partial shunting or short-circuiting of the heater. If, during the test, displacement of metal parts might occur due to the action of springs or the like, the latter are mechanically loaded as in normal use.
- 8.5 The test heater is energized by means of an extra-low voltage transformer adjusted so as to obtain the specified test power.

For controlling the test power, the current through the test heater as well as the voltage drop across the test heater is measured, the voltage drop being measured between the "cold" ends of the stranded leads connected to the resistance wire.

Unless otherwise specified in the relevant specification, the test power is applied for 30 min, after which the energy supply is switched off, the test heater remaining in position until the test results have been noted.
- 8.6 Unless otherwise specified in the relevant specification the test is made on three specimens.
- 8.7 When the relevant specification requires that the test be applied to more than one terminal in the same piece of equipment, care should be taken to ensure that any deterioration caused by one test will not affect the result of the next one.

Note. — If terminals and terminations and their supports are symmetrically designed, it may be sufficient to test only one terminal or termination.

- 8.8 The test heater shall be checked regularly for undue changes in resistance due to deterioration. If the resistance, measured in free air, differs from the original value (see Clause 4) by more than 10%, the heater shall be discarded. (The value of 10% is under consideration.)

9. Observations and measurements

During application of the test power and during the period the specimen is allowed to cool to approximately room temperature the specimen, the parts surrounding the specimen and the layer placed below it shall be observed.

- a) In the case of ignition of the specimen or of the parts surrounding it or of the layer placed below it, the duration of burning is measured and noted.

Duration of burning denotes the time interval during which flames are visible on the specimen, on parts in its vicinity or on the layer used for the test.

- b) The maximum height of any flame, but disregarding the start of the ignition, which may produce a high flame for a period of approximately 1 s, shall be measured and noted.

The height of the flame is the vertical distance between the visible tip of the flame and the upper surface of the burning item.

- c) Characteristics of the burning shall be noted.

- d) The specimen shall be examined visually for physical damage and the mechanical/electrical parameters measured as specified in the relevant specification.

10. Evaluation of test results

Unless otherwise specified in the relevant specification, the specimen is considered to have withstood the bad-connection test if one of the following two situations applies:

- there is no visible flame and no sustained glowing;
- flames or any glowing of the specimen, of the surroundings and of the layer extinguish within 30 s after ignition, and the surrounding parts as well as the layer have not burned down completely.

When a layer of tissue paper is used, the specimen is considered to have withstood the test if there is no ignition of the tissue paper and no scorching of the pine-wood board. A slight discolouration of the pine-wood board is neglected.

It may be necessary to carry out further tests on surrounding parts of the specimen by means of an adequate ignition source (see Clause 3). For this reason, the height of the flames and their duration have to be measured and noted during the bad-connection test.

11. Information to be given in the relevant specification

The relevant specification shall specify the following details:

- a) any preconditioning, if required (see Clause 6);
- b) the number of test specimens, if not three (see Sub-clause 8.6);

- c) the position of the specimen (see Sub-clause 8.2);
- d) the connection to be tested and the appropriate test heater (see Sub-clause 8.3);
- e) the underlying layer to evaluate the effect of burning or glowing particles (see Clause 4);
- f) the level of severity (see Clause 5):
 - the test power value,
 - the duration of application, if not 30 min;
- g) whether the test shall be made at more than one terminal on the same equipment (see Sub-clause 8.7);
- h) the requirements:
 - which of the two situations specified in Clause 10 shall apply for fire hazard assessment,
 - whether the criteria specified in Clause 10 are sufficient to check compliance with the safety requirements, or
 - whether additional criteria should be introduced;
- i) any deterioration of mechanical/electrical properties allowed.

APPENDIX A

INSTRUCTIONS FOR THE PREPARATION OF TEST HEATERS

A1. Introduction

For the bad connection test to be made on terminals and terminations, test heaters incorporating a resistance wire are required. The dimensions and the shape of the test heaters are related to the design and the size of the terminals and terminations and, as far as the test power is concerned, to the actual current carried by them.

Test heaters for terminals with screw clamping for the connection of external copper conductors to electrical equipment, can be prepared in accordance with the following instructions.

These instructions may also be used as a guide for preparing test heaters having other dimensions and shapes, taking into account the particulars given in Clause 4.

A2. Components of test heaters

The test heater consists of a piece of NiCr 6015 wire, which contains at least 59% nickel, 14% to 19% chromium and 19% to 23% iron and has a specific resistance, at a temperature of 20 °C, of 1.13 Ωmm²/m.

A lead of circular cross-section, composed of fine-wire copper strands and having a length of 120 ± 2 mm, is connected to each end of the heater by means of copper alloy sleeves (see Figure 1, page 28).

The preparation of the test heater necessitates the use of a pair of pliers with matching inserts or an equivalent crimping tool as well as solder having a silver content of at least 40% (see Figures 4 and 5, page 29).

For preparing test heaters having a helical shape, circular mandrels having an appropriate diameter are required.

A3. Dimensions and shape of test heaters

Table II specifies the dimensions of the resistance wire, of the stranded lead, of the sleeves and of the crimped connections for test heaters to be used for terminals with screw clamping as shown in Table III. The shapes of the test heaters are also specified in Table II.

Care should be taken to ensure that the recommended dimensions and the shape of the test heaters, and in particular the free length and the diameter of the resistance wires and of the stranded leads, are adapted to the conductor space of the terminal to be tested and to the heat dissipation resulting from the connection of one conductor of the nominal cross-sectional area when the maximum current occurring under normal conditions of use is carried by the terminal.

A4. Preparation of test heaters

- A4.1 Copper alloy sleeves are slipped over both ends of the 120 mm long stranded leads, care being taken to ensure that the twist of the lead does not alter and that no individual wires protrude from the sleeves.
- A4.2 The sleeves at one end of the two leads are then crimped parallel to the end of the lead by means of the appropriate crimping tool shown in Figure 4, page 29, or by appropriate pliers. These ends are called "cold" ends.
- A4.3 The other sleeves are positioned parallel with the other ends of the two leads and a hole is made in the centre of the lead within the sleeve by means of a pointed rod (such as a darning needle) of sufficient size to allow the resistance to be inserted.
- A4.4 The two ends of the resistance wire are inserted into the holes in the centre of the two leads.
- A4.5 The sleeves on the end where the resistance wire is inserted to the stranded lead are crimped by means of the crimping tool shown in Figure 4 or by appropriate pliers, care being taken to ensure that
- the narrow sides of the sleeves after crimping are in the same plane,
 - the sleeves are crimped over their full length, including the hole made in the end of the lead,
 - the dimensions a and b of the sleeves after crimping are those specified in Table II.
- A4.6 The crimped connections between the resistance wire and the stranded leads are then soldered, for which an adequate flux for liquefying the solder may be used.
- The solder shall be fed to the crimped connection from the side of the resistance wire, care being taken to ensure that a length of L_h (see Figure 1, page 28) remains free of solder and that no surplus solder penetrates into the leads outside the sleeves, because this may affect the mobility and heat conductivity of the leads. A suitable device for soldering is shown in Figure 5, page 29.
- A4.7 The test heater is then formed into shape U, shape W, shape C2 or C3 as required for the test. For these shapes, see Figure 2, page 28, and Table III.

Resistance wires having a diameter not exceeding 1.2 mm may be bent cold into the required shape.

Resistance wires having a diameter exceeding 1.2 mm shall be bent hot in order to prevent crack formation. Shape U is produced after heating the test heater to red hot by passing an appropriate current or by means of a gas flame.

For shape U and shape W, care should be taken to ensure that the narrow sides of the crimped sleeves are in the same plane and that the resistance wire is not twisted.

- A4.8 The test heater is electrically heated to red hot under normal atmospheric conditions and is maintained at this temperature for 10 min in order to insulate the resistance wire by oxidizing its surface.

TABLE II
Shapes and dimensions of test heaters

Test heater		Resistance wire			Test heater			Lead ³⁾	Sleeve before crimping			Sleeve after crimping	
No.	Shape	$d_h^{1)}$	$l_g^{2)}$	$L_h^{2)}$	$d_c^{1)}$	$L_c^{1)}$	$d_s^{2)}$	mm ²	mm ²	$L^{2)}$	$D_i^{2)}$	$a^{1)}$	$b^{1)}$
HP1	U	0.9	36	22	2.0	6.5	—	1.5	2.5	7	2.3	2.3	2.2
HP2	U	1.0	39	25	2.4	7.0	—	1.5	2.5	7	2.3	2.3	2.2
HP3	U	1.3	47	29	2.8	8.0	—	2.5	4.0	9	2.8	2.3	2.8
HP5	U	1.4	53	33	3.4	9.0	—	4.0	6.0	10	3.6	2.8	3.6
HP6	U	1.5	60	40	4.0	11.0	—	4.0	6.0	10	3.6	2.8	3.6
HP7	U	1.7	72	48	5.0	13.0	—	6.0	10.0	12	4.5	2.8	4.0
HS0	C2	1.0	41	27	—	—	2.9	1.5	2.5	7	2.3	2.3	2.0
HS1	C2	1.0	44	30	—	—	3.3	1.5	2.5	7	2.3	2.3	2.0
HS2	C2	1.2	49	35	—	—	3.8	1.5	2.5	7	2.3	2.3	2.0
HS3	C2	1.2	58	40	—	—	4.4	2.5	4.0	9	2.8	2.3	2.7
HS4	C3	1.2	87	69	—	—	5.5	2.5	4.0	9	2.8	2.3	2.7
HS5	C3	1.2	91	71	—	—	5.5	4.0	6.0	10	3.6	2.8	3.4
HS6	C3	1.2	94	74	—	—	5.5	4.0	6.0	10	3.6	2.8	3.4
HS7	C3	1.4	111	87	—	—	6.6	6.0	10.0	12	4.5	2.8	4.0
HM0	U	0.65	39	25	1.4	7.5	—	1.5	2.5	7	2.3	2.3	2.0
HM1	U	0.8	44	30	1.7	8.4	—	1.5	2.5	7	2.3	2.3	2.1
HM2	U	0.9	39	35	1.9	10.0	—	1.5	2.5	7	2.3	2.3	2.2
HM3	U	1.0	60	42	2.2	12.0	—	2.5	4.0	9	2.8	2.3	2.7
HM4	U	1.0	69	51	2.5	14.5	—	2.5	4.0	9	2.8	2.3	2.7
HM5*	W	0.8	80	60	4.2	16.0	—	4.0	6.0	10	3.6	2.8	3.4
HM6*	W	0.8	90	70	4.2	19.0	—	4.0	6.0	10	3.6	2.8	3.4
HM7*	W	0.8	110	86	4.2	23.0	—	6.0	10.0	12	4.5	2.8	4.0
See Figure	2	1			2			—	3			3	

1) Maximum value in millimetres.

2) Minimum value in millimetres.

3) Highly flexible lead.

* Provisional values.

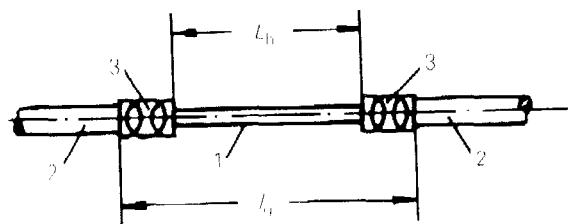
TABLE III

Reference number and shape of test heater suitable for terminals with screw clamping

Type of terminal	Current* (A)	Reference number and shape of test heater
Pillar terminal	10 16 25 32 32 40 63	HP1/U HP2/U HP3/U HP3/U HP5/U HP6/U HP7/U
Screw and stud terminal	6 10 16 25 32 32 40 63	HS0/C2 HS1/C2 HS2/C2 HS3/C2 HS4/C3 HS5/C3 HS6/C3 HS7/C3
Saddle terminal	25 32 32 40 63	HP3/U HP3/U HP5/U HP6/U HP7/U
Mantle terminal	6 10 16 25 32 32 40 63	HM0/U HM1/U HM2/U HM3/U HM4/U HM5/W HM6/W HM7/W

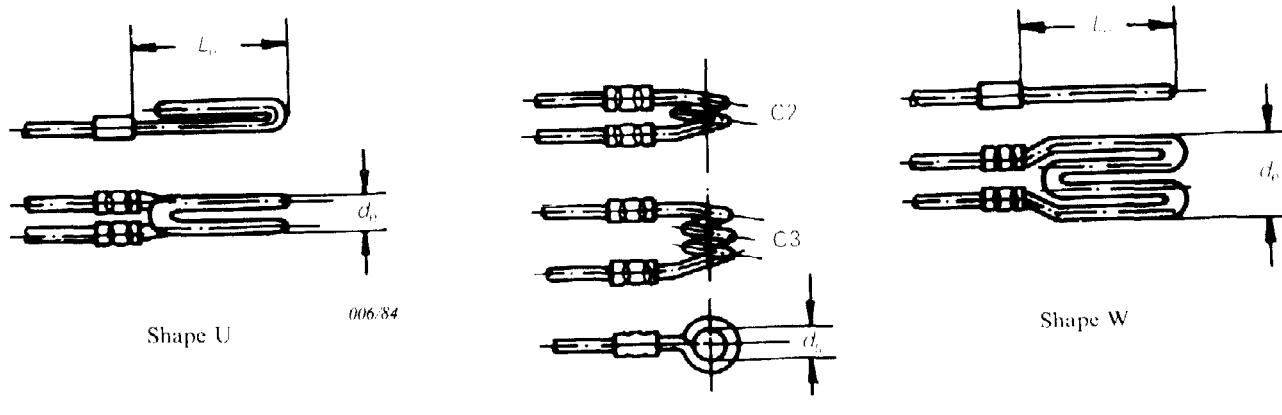
* Actual current carried by terminal under normal conditions of use.

Note. — Test heaters for tag and lug terminals are under consideration.



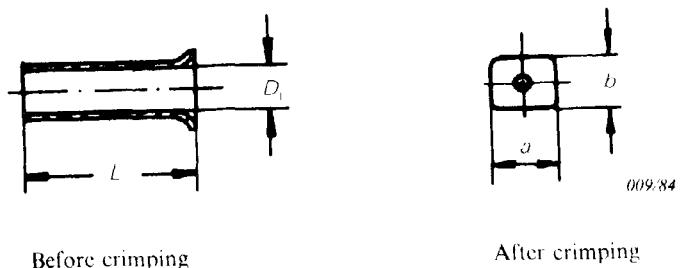
1 = resistance wire with diameter d_h
2 = lead 120 ± 2 mm long
3 = sleeve

FIG. 1. Dimensions of resistance wire.



Formes C2 et C3
Shapes C2 and C3

FIG. 2. – Shapes and dimensions of test heater.



Before crimping

After crimping

FIG. 3. – Dimensions of sleeves.

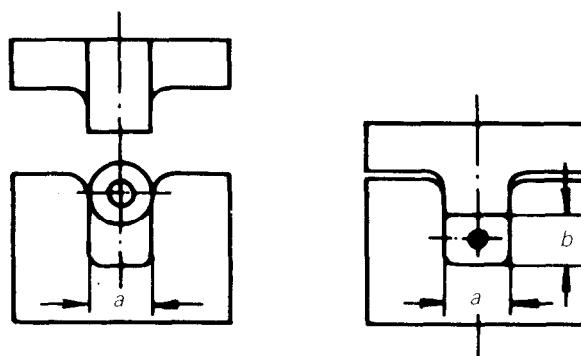
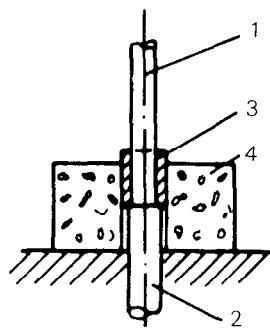


FIG. 4. — Example of soldering device.



- 1 = resistance wire
- 2 = lead
- 3 = sleeve after crimping
- 4 = fire proof support

FIG. 5. — Example of crimping tool.

Bureau of Indian Standards

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